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More landless, more problems: Investigating the relationship between land and income inequality in Africa

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Background: In pursuit of greater equality, African nations have implemented land reforms to increase land ownership among indigenous citizens. Despite these efforts, Africa remains one of the world's most unequal regions.

Aim: In line with the sustainable developmental goals (SDGs) 10 of the Equal World campaign, the study investigates how land ownership influences income inequality in African countries. We create a unique time series measuring landholders per square kilometre of agricultural land and explore its relationship with income inequality.

Setting: The analysis covered the period of 2000–2020, using data from the World Bank gender data portal and World Bank Development Indicators to compute the land inequality index.

Method: Conventional cointegration and advanced wavelet coherence techniques are employed to examine the influence of land ownership on inequality.

Results: Traditional estimators reveal a long-run positive relationship between land ownership and income inequality, with bi-directional causality, implying that African countries with higher (lower) land concentration are associated with higher (lower) levels of inequality. However, wavelet coherence analysis reveals that only 8 countries exhibit a positive relationship, while 16 show a negative relationship, and 2 show an insignificant relationship. Notably, most countries with a negative (positive) relationship (did not) implement additional land reforms after 2000.

Conclusion: We conclude that countries that fail to undergo continuous adjustments in land reforms risk experiencing a higher concentration of land ownership and income inequality. This study's findings underscore the importance of land policy updates for long-term equity.

Contribution: Unlike previous studies using the Gini Land coefficient, this study measure agricultural landowners per square kilometre, capturing the entire population and its relationship with income inequality.

Keywords: land ownership; income inequality; cointegration; causality; wavelet coherence; partial wavelet coherence; Africa.

Introduction

Despite being a recurrent theme in sustainable developmental goals (SDG) and agendas, the persistence of income and wealth inequality in Africa remains a critical challenge. A wide income gap's economic and social ramifications are substantial, impacting economic growth and poverty alleviation (Cornia 2019; Fosu 2009). Despite policy efforts, income inequality persists in Africa, hindering development and rendering the fight against poverty alleviation less effective (Acemoglu & Robinson 2010; Raimi & Phiri 2024).

Africa consistently ranks high in all dimensions of income inequality. Some countries, such as South Africa, the Central African Republic, Namibia, Mozambique and Zambia, are consistently among the most unequal globally (Odusola et al. 2017). Regional statistics reveal that 54% of the total income in Africa is concentrated in the top 10 wealthiest families, with income inequality either stagnant or increasing over the last three decades (African Development Bank 2012; Odusola et al. 2017). Notably, the income gap between the top 10% of the highest earners and the bottom 50% remains unacceptably high, deviating from the global trend of reduced unequal income distribution since the 1990s (Odusola et al. 2017).

Note: Additional supporting information may be found in the online version of this article as Online Appendix 1 and Online Appendix 2.

While various factors contribute to income inequality in Africa, unequal land distribution has emerged as a significant driver (Chancel et al. 2023; Cornia et al. 2017; Raimi & Phiri 2024). Land inequality is posited as the root of inequality in many African countries, with the initial land asset distribution considered more impactful than the income distribution (Anseeuw & Baldinelli 2020). For instance, land ownership is crucial collateral influencing credit access, income generation and heritage (Ardina et al. 2022; Birdsall & Londono 1997). However, as seen in southern African countries, land concentration, among a few, diminishes agricultural efficiency by fostering reliance on cheap labour rather than nurturing entrepreneurship in the farming sector. This impedes investments in education and human capital development, perpetuating rural poverty (Ayaz & Mughal 2023; Bjornlund, Bjornlund & Van Rooyen 2020). Therefore, inequalities in land distribution tend to persist over generations and potentially exacerbate unequal wealth distribution in the long run (Galli & Ronnback 2021).

Recognising the importance of equitable land distribution, studies have emphasised the role of land in economic growth, human capital development and poverty (Anseeuw & Baldinelli 2020; Cipollina, Cuffaro & D'Agostino 2018; Deininger & Olinto 1999; Deininger & Squire 1998; Erickson & Vollrath 2004; Gottlieb & Grobovšek 2019; Phiri & Ngeendepi 2021). Remarkably, African countries where land and income inequality are pronounced have received scant empirical attention. Authors often attribute this gap to challenges in obtaining data for measuring land inequality (Azadi & Vanhaute 2019; Erickson & Vollrath 2004).

Given these gaps, our study investigates the relationship between agricultural land ownership and income inequality in African countries. To explore this relationship, we created a unique but simple time series measure of agricultural land holdings or land concentration for 26 African countries, which measures the number of landowners per square kilometre of agricultural land. We use these data to investigate the empirical relationship between land ownership and African income inequality between 2000 and 2022. Considering that our proposed analysis covers a period plagued by years of structural breaks, traditional econometric techniques may not be adequate for capturing time and cyclical variations. Therefore, we turn to a partial wavelet coherence framework that allows us to examine the co-movement between agricultural landholdings and income inequality scale-by-scale at different periods while controlling for economic growth. Moreover, our data series is long enough (allow us) to conduct a country-by-country analysis, circumventing the issue of country heterogeneities associated with panel or cross-sectional estimators commonly used in the literature.

Our traditional panel regression results show an unexpected positive relationship between land ownership and income inequality across the panel. However, wavelet coherence analysis reveals this positive relationship in only eight countries at specific times and frequency cycles. The majority of other countries maintain a consistent theoretically negative relationship. Notably, countries that did not undergo reforms after 2000 tend to exhibit negative land inequality relationships. Our findings underscore the need for continuous formal land reform processes over the long term. African countries that have not reformed past their former 'state-centric' land policies from the 1960s and 1970s risk perpetuating skewed land ownership distributions that worsen inequality. Additionally, governments that have recently implemented land reforms must consider factors like gender disparities to avoid exacerbating land inequality and income disparities.

The remainder of this article is structured as follows. The section titled 'Overview of land reform in Africa' provides an overview of land reform specifically in Africa. The 'Literature review' section offers a theoretical basis for understanding land inequality and reviews relevant literature. In the 'Methodology' section, we outline the approach we used, while the 'Data and results' section provides a description of the data and presents the findings from our empirical analysis. Finally, the study is concluded in the last section.

Overview of land reform in Africa

The origins of land inequality in Africa can be traced back to its early developmental stage, with colonialism identified as a major driver (Galli & Rönnbäck 2021). Even after African independence, the legacy of colonial institutions continued to perpetuate land concentration and inequality, necessitating calls for land reform (Acemoglu et al. 2014; Acemoglu, Johnson & Robinson 2002; Acemoglu & Robinson 2012). In response, many African countries initiated widespread land and agrarian reforms, often spearheaded by the government or through revolutionary means (Ochieng 2020).

The earliest reforms date back to the 1960s and 1970s, coinciding with most African countries' attainment of political independence (Anseeuw & Baldinelli 2020). These reforms were formalised as land acts to eliminate previous oppressive and discriminatory colonial land management practices (Peters 2004). However, based on 'customary' systems, these early reforms failed to provide the necessary 'security' to encourage agricultural investment and the productive use of land. Instead, they facilitated speculation and land expropriation by outsiders, often exacerbating conflicts (Peters 2009).

Early analyses indicate that customary or communal law and tenure were products of colonialism, jointly established by African leaders to serve the interests of a minority (Colson 1971; Kohlhagen 2011; Mamdani 2017; Moore 1986). Studies in the early 2000s revealed that customary tenure was essentially a compilation of former colonial laws, retaining many shortcomings (Berry 2002; eds. Kuba & Lentz 2005; Spear 2003). Subsequent research demonstrated that customary law was not merely a written version of oral traditions but significantly influenced by colonial conditions, serving to benefit the state, European settlers and wealthy Africans (Peters 2009). A common conclusion drawn from this literature is that initial reforms in many African countries favoured elite and state interests, leading to their inevitable failure within African societies and necessitating further land reforms in several countries.

To address the perceived shortcomings of previous land policies, some African countries embarked on additional land reforms in the 2000s and 2010s. Among the most well documented of these newer reforms are Tanzania's 1999–2000 Land Act (Pedersen 2015, 2016), Mali's 2000–2002 Land Tenure Code (Totin et al. 2021), Malawi's 2002 Land Policy (Chikaya-Banda & Chilonga 2021; Chinsinga 2011), Namibia's 2002 Communal Land Reform Act (Mudau, Mukonza & Ntshangase 2018), Zimbabwe's 2002 Land Acquisition Act (Mkodzongi & Lawrence 2019), Burundi's 2004 revised Land Code (Tchatchoua-Djomo 2018), Rwanda's 2005 Land Law (Pottier 2006; Pritchard 2013), Burkina Faso's 2007–2012 revised Land Laws and reforms (Bambio & Agha 2018), Lesotho's Land Act of 2010 (Fogelman 2016), Kenya's 2012 Land Act, Land Registration, and National Land Commission Act (Manji 2014), Benin's 2013 Land Law (Delville 2020; Ekpodessi & Nakamura 2018) and Liberia's 2013 Lands Right Policy (Brown 2017).

However, while the new wave of land reforms in the 2000s aimed to rectify the unequal distribution of colonial legacies and restructure land resources more rationally by transforming large-scale farms into indigenous family farms for productive use, the methods and processes in many countries were not pragmatic, leading to low implementation rates (Pedersen 2016). For instance, Mali, Burundi and Tanzania's attempts to transfer land governance to village authorities to facilitate land registration and titling were short lived. In Tanzania, this was partly because of legislative complexity, while in Mali, the code lacked enforceability because it lacked an 'implementation decree' requiring approval from council ministers, thus creating implementation disputes (Pedersen 2016; Totin et al. 2021). In the case of Burundi, despite the inclusion of land decentralisation in the 2000 Arusha Peace Agreement to enhance tenure security through property rights registration, the process was largely unsuccessful, mainly because of a lack of political will to implement the peace agreement. By the end of the 2000s, only 46 000 plots had been duly registered, representing less than 1% of the country's land (Kohlhagen 2011; Tchatchoua-Djomo 2018).

Similarly, the ineffective reform in Kenya in 2010 is attributed to the influence of veto players who hindered the reform's implementation for political reasons and the lack of apparent constitutional authority for the newly established National Land Commission (NLC), tasked with reclaiming illegal and undocumented public land through legal means (Boone et al. 2019). The reform in Zimbabwe, aimed at creating new commercial black farmers, primarily resulted in malnutrition and economic failure. This occurred because the process failed to transfer land rights to black individuals already engaged in businesses, especially in the Small, Medium and Micro Enterprises (SMMEs) sector – the true black entrepreneurs. Instead, it transferred commercially successful assets to political elites lacking business acumen or skills (Gumede 2018).

Contrary to the cases of the aforementioned countries, Rwanda's reform, designed to map and digitise land title records, was partly successful because it did not stop with the land titling programme but concentrated on fighting land corruption, perceived as a major factor in Rwanda's conflict (Pritchard 2013). Like Rwanda, Burkina Faso, in addition to transferring land management from the central government to local authorities, also established technical support services to assist local governments in managing land responsibilities and safeguarding the interests of women and vulnerable groups (Elbow 2019). Lesotho's reform was also reported as successful partly because the process focussed on agricultural development and economic investment (Fogelman 2016). The reform reduced the mandatory 51% share that goes to Basotho nationality when foreign investors acquire land to 20% to attract more foreign investors, address tenure security and allow land to serve as collateral for financial loans. Lastly, the reform abolished the previous gender land-ownership bias and allowed for sole female land ownership registration and access to credit (Fogelman 2016).

Namibia and Malawi's reform policies were also in direct contrast to Zimbabwe's approach of forceful distribution, but the initiative was based on willingness to buy and sell (Chinsinga 2011). Namibia's approach consisted of two strategies: resettlement (Government purchase of land and allocation to vulnerable groups) and communal land (state-owned land is parcelled into small units and allocated by traditional authority). These strategies transferred over 1000 commercial land to previously disadvantaged Namibians through private and government-facilitated transactions (Engelbrecht 2014). Another exceptional case exists for Malawi, which boasts low levels of land inequality owing to its successful reform strategies of land tenure regularisation, strengthening land administration, land use planning, protection of customary land rights, promotion of investment in agriculture and formalisation of customary land rights as private land rights in customary estates, increasing land ownership for indigenous households (Byamugisha 2013).

In general, Eastern and Southern African countries such as Kenya, Tanzania, Zambia, Zimbabwe and South Africa are notorious for their high levels of land inequality, whereas Western and Central African countries such as Ghana, Sierra Leone, Togo and Burkina Faso are among the most egalitarian in the world (Bernstein 2003; Frankema 2005; Mudau et al. 2018). Bernstein (2003) notes that land inequality in Southern Africa is more persistent than in other regions of Africa as these countries struggled to obtain liberation from the rule of colonial political regimes before the 1990s. However, recent reforms have helped correct the tragedy in Malawi and Namibia.

Literature review

Theoretical underpinnings

The significance of land in economic theories is deeply rooted in its role in sustaining agricultural output to meet society's food and textile needs. Various economic schools have incorporated land into their theories, recognising its contributions to economic development. Initially considered the primary source of wealth, land has maintained its importance even in schools, such as mercantilism, which focusses on trade and human capital. Technological innovation has expanded this perspective by acknowledging other valuable resources in the soil (Hubacek & Van Den Bergh 2002).

The economic importance of land traces back to medieval times when agricultural activities formed the cornerstone of a country's economy (Haney 1964). Physiocrats consider land the source of economic surplus, emphasising its role in determining agricultural output and net product, influencing a country's economic activities (Meek 1963).

A notable historical debate on land and agriculture was the United Kingdom Corn Laws discussion (1815–1846), centring on tariffs and trade restrictions impacting cereal grain prices. Influential essays during this period, such as Ricardo's on the profit of stock and Malthus's inquiry into the nature of rent, shaped economic ideologies and highlighted the influence of landowners on agricultural prices (Blaug 1997).

Adam Smith viewed agriculture as the primary source of wealth, Cantillon identified land as the primary input and Malthus advocated cultivating more land to mitigate the poverty resulting from population growth (Aspromourgos 1998). Modern economic theories, including classical, neo-classical and neo-institutionalist perspectives, emphasise the importance of land in food production and societal transformation.

While common land rights can shift to private property regimes because of population pressure and land scarcity, a secure land tenure system is crucial for avoiding conflicts, instability and the exclusion of vulnerable groups. Such a system catalyses multiple benefits, including poverty eradication, food security, economic growth and significant investment incentives. Ensuring more access to land is essential, considering its pivotal role in the economic development process (Wegerif & Guereña 2020).

Empirical review

Notably, few quantitative studies have been conducted on the impact of land inequality on economic development, with most studies focussing on the impact of land inequality on economic growth (Cipollina et al. 2018; Deininger & Olinto 1999; Deininger & Squire 1998; Erickson & Vollrath 2004; Fort 2007; Frankema 2005). However, only the studies by Carter (2000), Wegerif and Guereña (2020) and Qasim, Pervaiz and Chaudhary (2020) directly connect land inequality to income inequality. However, while Carter (2000) focusses on Africa, Asia, Latin America, Eastern Europe and Organisation for Economic Co-operation and Development (OECD) countries, the author acknowledges that Africa has the weakest dataset. None of the 10 African countries included in the study had more than two data points. On the other hand, the study by Wegerif and Guereña (2020) is restricted to the trend of land policy, leaving only the study by Qasim et al. (2020) that empirically investigates the relationship between land inequality, poverty and income inequality. We discuss these studies as follows:

Deininger and Squire (1998) investigated the connection between income inequality, asset inequality and economic growth in seven global regions, including sub-Saharan Africa and Middle East and North Africa (MENA) countries. They found a robust negative relationship between initial land inequality and long-term growth. Moreover, the study supported Barro and Lee's (2001) view that inequality reduces growth in developing countries but not developed ones. In contrast, the authors provide little support for the Kuznets relationship between income inequality and economic growth.

Deininger and Olinto (1999) employ the generalised moment method estimator to study the relationship between inequality and growth. The authors find that assets via land inequality, not income inequality, have a relatively large negative impact on economic growth. The authors further revealed that vast inequality in asset distribution limited human capital development and stressed that household access to more assets is more crucial for development than equal income distribution because higher land inequality can hamper education reform.

Erickson and Vollrath (2004) examine the relationship between land inequality and institutions, financial development and education. The authors used both measures of inequality that capture only inequality within landholders and other measures that show inequality across agricultural populations. Firstly, the data were subjected to ordinary least squares (OLS) analysis, and the results showed no relationship between land inequality and institutions. Secondly, the analysis failed to find any relationship between unequal land distribution and financial development. Furthermore, the authors could not establish a relationship between high land inequality across agricultural populations and low educational levels. However, less unequal land distribution among the agricultural population was observed, encouraging government spending on education.

In another cross-country study, Frankema (2005) explored the causes and consequences of historical land distribution using data compiled by Deininger and Olinto (1999). Employing a panel regression estimator, the results show a weak, direct relationship between land and income inequality. However, a strong relationship between the initial land inequality and current income inequality was revealed when controlling for colonial institution variables. Additionally, the study revealed that high-income inequality in sub-Saharan Africa and Latin America is rotated in different colonial origins.

Fort (2007) also employed the system general method of moments estimator (GMM) to investigate the relationship between land inequality and economic growth in over 30 countries using Food and Agriculture Organization (FAO) agricultural census data. The study included countries from Asia, Europe, the Middle East and the United States of America. The study found a significant negative relationship between land inequality and economic growth and stressed the importance of asset distribution in the development process. The study further confirmed the hypothesis that although investment in human capital encourages economic growth, unequal asset distribution reduces the effectiveness of education policies.

Cipollina et al. (2018) further examined the empirical relationship between unequal land distribution and economic growth using a meta-data analysis based on previous publications on land inequality. Their meta-analysis showed that unequal land distribution negatively affects economic growth, especially at low development levels. However, their panel result analysis shows a positive correlation between land inequality and economic growth in the short run but a negative impact of land inequality in the long run because of credit constraints and institutional mechanisms identified in the Galor-Zeira model.

More recently, Qasim et al. (2020) investigated the mediating role of poverty and agricultural land inequality on human capital development in 34 districts in Punjab, Pakistan, between 2003 and 2014. Employing two-stage least squares (TSLS) and GMM estimators, the authors find that: (1) agricultural land inequality has a positive relationship with poverty and income inequality in the first-stage regressions and (2) poverty and income inequality have a negative relationship with human capital development in the second-stage regressions.

Contribution to literature

While we acknowledge the preceding empirical studies, we identify and address three gaps to advance understanding of the relationship between land inequality and income inequality in African countries. The gaps are as follows:

- **Limited focus on African countries**: Although studies such as Deininger and Squire (1998) and Carter (2000) included African countries, their datasets were inadequate, and scant empirical attention was given to African nations. Our study concentrates directly on African countries and utilises a more robust dataset with a unique time series measure of agricultural land holdings, providing a more precise analysis of the relationship between land inequality and income inequality in Africa.
- **Measurement of land inequality**: Most studies rely on the Gini Land coefficient to measure land inequality, which may not effectively capture the nuances of land distribution. We address this gap by introducing a novel measure of land inequality, precisely the number of agricultural landowners per square kilometre. This measure offers a more accurate and contextually relevant understanding of land distribution in African countries. We detail the construction of land ownership data in the 'Measurements of land inequality' section.
- **Country-specific analysis**: Most studies employ cross-country or panel data approaches that may not account for the heterogeneity among African countries. We address this gap by providing country-specific analyses that allow for examining distinct national contexts. This approach helps to understand how different policies, historical factors and socio-economic conditions influence the relationship between land ownership and income inequality in individual African countries.

By addressing these gaps, our study contributes to a more comprehensive understanding of the relationship between land ownership and income inequality in Africa, offering valuable insights that can inform both academic debates and policy interventions.

Measurements of land inequality

The traditional method of measuring land inequality has always used the Gini coefficient, similar to other dimensions of inequality. The land Gini coefficient was computed from the agricultural data census published by the United Nations FAO. However, this inequality data only considers the unequal land distribution among landholders based on the total size of their holdings. It overlooks the landless population, which often comprises the impoverished segment of society. For example, if the entire land of a community of 100 people is distributed equally among the four landholders, the traditional Gini coefficient within the landholder would be zero, which is a case of perfect equality. However, this inequality calculation captures only 4% of the community's 100 population, excluding 96% of the landless population.

As such, land distribution Gini computed with agricultural census data, as used by Taylor and Hudson (1972) and Deininger and Squire (1998), has been criticised for being unidimensional and misses out on some important indicators of land inequality (Bauluz, Govind & Novokmet 2020; Erickson & Vollrath 2004). Anseeuw and Baldinelli (2020) claimed that the land Gini coefficient captures only the destitution of the size of farms rather than land ownership and does not account for multiple land holdings by individuals.

Erickson and Vollrath (2004) further stress that Agricultural Census data only focusses on individuals or households with land; it does not account for landless households and also fails to distinguish different forms of land ownership. In their response, Erickson and Vollrath (2004) devised a comprehensive land index that considers landholders and the landless population. They termed this index the 'average number of people working on any single holding', using data from the total agricultural population and the overall number of landholdings.

We adopt an approach similar to that of Erickson and Vollrath to create a land index for African countries. However, while Erickson and Vollrath's index is based on FAO land census data, we computed our land index data using agricultural land (sq. km), the share of the country's arable land area under permanent crops or pastures. We computed the land concentration measurements in two steps. Firstly, we obtained the number of landowners by multiplying the percentage of males and females who owned land with the population of males and females, respectively. Secondly, we divide the total number of landowners by agricultural land (sq. km), respectively:

$$LO = \frac{\left(\%\ Men\,Ownership\ of\ Land\ x\ Population,\ Male\right) + \left(\%\ Women\,Ownership\ of\ Land\ x\ Population,\ Women\right)}{\text{Agricultural land}\left(\text{sq.km}\right)} \quad \text{[Eqn 1]}$$

where LO is land ownership concentration, a lower (higher) number of landowners per square km indicates higher (lower) land inequality. Note that from Equation 1, the data for percentage of men and women who are land owners is obtained from the World Bank gender data portal,[1] while the data for agricultural land is from the World Bank Development Indicators (WBDI).[2] For land ownership, the preceding survey figures serve as the basis for calculations until a subsequent survey is conducted, as these surveys are infrequent and data on inequalities does not fluctuate rapidly (Erickson & Vollrath 2004).

The justification for using this measure stems from the unavailability of data to compute the land Gini coefficient in many African countries and the limitations of its calculation, as discussed earlier in this article. Calculating the land Gini coefficient requires agricultural survey data, typically conducted by the United Nations FAO every 10 years. However, several African countries have yet to conduct an agricultural census since gaining independence, and in some cases, the census results were inconclusive. Alternatively, we rely on World Bank data regarding the percentage of men and women who own land in each country, similar to FAO census data. The uniqueness of our index lies in its ability to capture the widespread distribution of land holdings across the relevant population. Specifically:

- The measure encompasses the entire population of men and women at a given time, accounting for both landowners and the landless population – something the conventional Gini coefficient overlooked.
- It estimates the percentage of the population that owns land from the entire population at a given time.
- It assesses the distribution of land within the country.

Methodology

Empirical model

Following the theoretical guidance, the regression for the study is specified thus:

$$I/I_t = \beta_{10} + \beta_{11}\, L/O_{it} + \beta_{12}\, GDP_{it} + \text{error} \quad \text{[Eqn 2]}$$

While the second regression is:

$$L/O_t = \beta_{00} + \beta_{21}\, I/I_{it} + \beta_{22}\, GDP_{it} + \text{error} \quad \text{[Eqn 3]}$$

where I/I = Income inequality, L/O = Land ownership index and gross domestic product (GDP) is economic growth. Based on the literature, we expect a negative relationship between income inequality and land ownership diversification, as well as between income inequality and GDP (i.e. β_{11}, β_{21}, $\beta_{12} < 0$). In contrast, a positive relationship is expected between GDP and land ownership diversification (i.e. $\beta_{12} > 0$). To estimate the baseline regressions, we rely on the pooled mean group (PMG) estimators of Pessaran et al. (1999), the Granger causality tests of Dumitrescu-Hurlin (2012) and the wavelet coherence analysis of Torrence and Compo (1998) and Mihanović, Orlić and Pasarić (2009). The methods are discussed in the following subsections.

Pooled mean group estimators

To estimate the baseline regression, we rely on the PMG estimators, which are an intermediate estimator between the mean group (MG) and the traditional pooled Dumitrescu-Hurlin (2012) autoregressive distributive lag (P-ARDL (p, q, q … … .q) model:

$$I/I_{it} = \sum_{j=1}^{p} \lambda_{ij} I/I_{i,t-j} + \sum_{j=0}^{q} \delta_{1oij} L/O_{i,t-j} + \sum_{j=0}^{q} \delta_{2ij} GDP_{i,t-j} + \alpha_i + \varepsilon_{it} \quad \text{[Eqn 4a]}$$

$$L/O_{it} = \sum_{j=1}^{p} \lambda_{ij} L/O_{i,t-j} + \sum_{j=0}^{q} \delta_{1ij} I/I_{i,t-j} + \sum_{j=0}^{q} \delta_{2ij} GDP_{i,t-j} + \alpha_i + \varepsilon_{it} \quad \text{[Eqn 4b]}$$

The I/I = Income inequality is the dependent variable in Equation 4a while L/O = Land ownership index serves as the dependent variable in Equation 4b, other variables serve as the independent variables, defined as α_i is the fixed effect, λ_{ij} and δ_{ij} are the vectors of the parameters. The error correction representation of Equation 2 is:

$$\Delta I/I = \phi_i I/I_{i,\,t-1} + L/O_{it}\beta_{1i} + GDP_{it}\beta_{2i} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta I/I_{i,t-1} + \sum_{j=0}^{q-1} \Delta L/O_{i,t-j}\delta^*_{1ij} + \sum_{j=0}^{q-1} \Delta GDP_{i,t-j}\delta^*_{2ij} + \mu_i + \varepsilon_{it} \quad \text{[Eqn 5a]}$$

1.https://genderdata.worldbank.org/indicators/sg-own-ld/?gender=male&ownership=Do%20not%20own&view=correlation.

2.https://data.worldbank.org/indicator/AG.LND.AGRI.K2.

$$\Delta L/O = \phi_i L/O_{i,\,t-1} + I/I_{it}\beta_{1i} + GDP_{it}\beta_{2i} + \sum_{j=1}^{p-1}\lambda_{ij}^{*}\Delta L/O_{i,t-1} + \sum_{j=0}^{q-1}\Delta I/I_{i,t-j}\delta_{1ij}^{*} + \sum_{j=0}^{q-1}\Delta GDP_{i,t-j}\delta_{2ij}^{*} + \mu_i + \varepsilon_{it} \qquad \text{[Eqn 5b]}$$

where 'ε_{it}' are serially not correlated across *i and t*, have zero means, variance $\sigma_i^2 > 0$ and finite fourth-order moment conditions, and:

$$\phi_i = -1\left(1 - \Sigma_{j=1}^{p}\lambda_{ij}\right) \textit{ and } \beta_i = \sum_{j=0}^{q}\delta_{ij} \qquad \text{[Eqn 6]}$$

The long-run relationship can compactly be denoted as:

$$y_{it} = \theta_i x_{it} + \eta_{it} \qquad \text{[Eqn 7]}$$

where $\theta_i = -\beta_i^{'}/\phi_i$ are the long-run coefficients and η_{it} is a stationary process. The long-run coefficients defined by θ_i are constrained to be the same for all cross-sectional units, and the error correction term is computed as:

$$\xi_i(\theta) = y_{i,-1} - X_i\theta, \ \ i = 1,2, \ldots N \qquad \text{[Eqn 8]}$$

The error correction term measures the speed of 'correction' back to steady-state equilibrium following a shock to the system of time series variables.

To test for cointegration effects, we rely on Pedroni's (1995, 2004) cointegration testing procedure, which requires us to extract the error term $e_{i,t}$ from the PMG estimators and construct the following test regressions:

$$e_{i,t} = \psi_i e_{i,t-1} + \Delta e_{i,t-1} + \Delta e_{i,t-2} + \ldots + \Delta e_{i,t-p} + v_{i,t} \qquad \text{[Eqn 9]}$$

$$e_{i,t} = \psi_i e_{i,t-1} + v_{i,t} \qquad \text{[Eqn 10]}$$

From Equation 9, we test the null hypothesis of no cointegration effects (i.e. H_0: $\psi_i = 1$ for all against the alternative of cointegration effects (i.e. H_{11}: $\psi_i = \psi < 1$), whereas from Equation 10, the null hypothesis of no cointegration (i.e. H_{10}: $\psi_i = 1$ for all) is tested against the alternative of cointegration effects (i.e. H_{11}: $\psi_i < 1$, $\psi_i \neq \psi$). Pedroni (1995, 2004) proposes four within-dimension (i.e. panel cointegration) statistics and three between-dimension (i.e. group mean panel) statistics to test for the different sets of formulated hypotheses that will be compared to critical values reported in Pedroni (1995, 2004).

Dumitrescu-Hurlin (2012) causality tests

To examine the causal relationship between land inequality and income inequality, we rely on the panel causality test of Dumitrescu-Hurlin (2012), who suggests the following regression:

$$I/I_{it} = c_i + \sum_{i=1}^{n}\alpha_i I/I_{i,t-j} + \sum_{i=1}^{n}\beta_{1i}\Delta L/O_{i,t-j} + \sum_{i=1}^{n}\beta_{2i}\Delta GDP_{i,t-j} + e_{i,t} \qquad \text{[Eqn 11]}$$

where $\beta_i = [\beta_i^{(1)}, \ldots]..,\beta_i^{(k)})$. Dumitrescu-Hurlin (2012) proposed testing the hypothesis of Homogeneous Non-Causality by accounting for both the heterogeneity in the regression model and the diversity in causal relationships across cross-sectional units, the hypothesis is defined as

$$H_0: \beta_i = 0, \forall i = 1, \ldots., N \qquad \text{[Eqn 12]}$$

where $\beta_i = [\beta_i^{(1)}, \ldots]..,\beta_i^{(k)})$. Under the alternative hypotheses, we assume the existence of $N_1 < N$ individual processes with no causality from x to y, while the remaining process $N_2 = N - N_1$ process has causality, that is:

$$H_1: \beta_i = 0 \ \forall i = 1, \ldots., N_1 \qquad \text{[Eqn 13]}$$

$$\beta_i = 0 \ \forall i = N_1+1, N_1+2\ldots, N$$

Dumitrescu-Hurlin (2012) proposed using the following average individual Wald statistic to test the Homogeneous non-causality (HNC) null hypothesis:

$$W_{N,T}^{Hnc} = \frac{1}{N}\sum_{i=1}^{N}W_{i,T} \qquad \text{[Eqn 14]}$$

where $W_{i',T}$ denotes the individual Wald statistic for the *i*th cross-sectional unit, corresponding to the individual causality hypothesis H_0: $b_i = 0$. Dumitrescu-Hurlin (2012) notes that individual Wald statistics provide undesirable distribution properties in small samples; hence, the authors propose the following approximated standardised statistics:

$$Z_{N,T}^{Hnc} = \sqrt{\frac{N}{2N}}\left(W_{N,T}^{Hnc} - K\right) \qquad \text{[Eqn 15]}$$

$$\hat{Z}_N^{Hnc} = \frac{\sqrt{N}[W_{N,T}^{Hnc} - E\left(\hat{W}_{i,T}\right)}{\sqrt{Var(\hat{W}_{i,T})}} \qquad \text{[Eqn 16]}$$

the second-order moments of the individual Wald statistics, $W_{i,T,}$ exist only if the condition $T > 5 + 2K$ holds. Our study limited the lag length to $K = 5$, given that our sample size consisted of 23 observations.

Wavelet coherence analysis

Wavelets are functions with certain mathematical conditions that divide data into different frequency components and study each component with a resolution matched to its scale (Zeevi & Coifman 1998). The usual procedure for analysing data using the wavelet technique is to adopt a prototype or transformation function called a mother wavelet, which consists of a series of daughter wavelets. In time-series analysis, the main goal of adopting a wavelet is to examine the time-frequency distribution of a data series and show how power evolves over time. Time series data are decomposed into time and frequency components to observe the time-frequency distribution between any two time-series datasets (dependent and independent) to understand how the relationship between the two series evolves over a time period (Torrence & Compo 1998).

Drawing from the wavelet concept, a three-step wavelet coherence procedure, as described in the studies of Aguiar-Conraria and Soares (2014) and Mihanović et al. (2009), was employed to examine the relationship between land index (y), income inequality ($x1$) and economic growth ($x2$) in time-frequency space. For our analysis, we focussed on the continuous wavelet tools. Firstly, we decomposed each variable with a matching 'daughter wavelet' as described above to produce a wavelet coefficient that reveals the similarity between the prototype function and various frequencies contained in the analysed signal. The daughter wavelet of each variable is defined as follows:

$$W_y(e,\tau) = |e|^{-\frac{1}{2}} \int_{\infty}^{\infty} y(t)\, \psi^*\left(\frac{t-\tau}{e}\right) dt \quad \text{[Eqn 17]}$$

$$W_{x1}(e,\tau) = |e|^{-\frac{1}{2}} \int_{\infty}^{\infty} x1(t)\, \psi^*\left(\frac{t-\tau}{e}\right) dt \quad \text{[Eqn 18]}$$

$$W_{x2}(e,\tau) = |e|^{-\frac{1}{2}} \int_{\infty}^{\infty} x2(t)\, \psi^*\left(\frac{t-\tau}{e}\right) dt \quad \text{[Eqn 19]}$$

where $W_{y\,,x1,\,x2}$ (e,τ) are the wavelet coefficients, e represents the scaling parameter, τ is the shifting/translational parameter (various combinations of e and τ lead to different daughter wavelets), the asterisk (*) is the complex conjugation, t is the time and ψ is the mother wavelet. Our mother wavelet is represented by the Morlet wavelet in Equation 17, Equation 18 and Equation 19, which consists of a modulated Gaussian width of K_0/π:

$$\psi(t) = \pi^{-\frac{1}{4}} \exp(iw_c t) \exp\left(-\frac{1}{2}t^2\right) \quad \text{[Eqn 20]}$$

The K_0 is the envelope factor that determines oscillations in a wave packet. For a good outcome with a zero (0) mean, we set $k_0 = 6$. Secondly, we extracted the power spectrum of our variables to examine the characteristics of each time-series dataset and denoted it as follows:

$$WPS_y(\tau, s) = |W_y(\tau, s)|^2 \quad \text{[Eqn 21]}$$

$$WPS_x(\tau, s) = |W_x(\tau, s)|^2 \quad \text{[Eqn 22]}$$

The brackets in Equation 21 and Equation 22 represent the expected values. WPS_y and WPS_x are the powers of signal $x(t)$ at a certain t (time) on an s (scale). From the power spectrum defined in Equation 21 and Equation 22, we derive the Cross-Wavelet Power spectrum as follows:

$$(CWPS)_{xy} = W_{xy} = |W_{x,y}| \quad \text{[Eqn 23]}$$

From which wavelet coherence is computed as follows:

$$R_{(y,x1)} = \frac{S[W(y,x1)]}{\sqrt{S[W(y)]\, S[W(x1)]}} \quad \text{[Eqn 24]}$$

$$R_{(y,x2)} = \frac{S[W(y,x2)]}{\sqrt{S[W(y)]\, S[W(x2)]}} \quad \text{[Eqn 25]}$$

$$R_{(x1,x2)} = \frac{S[W(x1,x2)]}{\sqrt{S[W(x1)]\, S[W(x2)]}} \quad \text{[Eqn 26]}$$

$W(.)$ is the wavelet transform, S is the smoothing operator of both time and scale, without which the coherence is identical to 1 at all scales and times. The phase difference dynamics are determined as follows:

$$\phi_{x,y} = Arctan^{-1}\left(\frac{I\{W_{xy}\}}{\Re\{W_{xy}\}}\right). \quad \text{[Eqn 27]}$$

where $\pi < \varphi_{x,y} < -\pi$ and provides information on whether the relationship between two pairs of variables is positive (in-phase) or negative (anti-phase). It also provides the direction of causality, whether x leads y or vice versa. Finally, Wavelet Coherence is extended to eliminate the influence of other variables by transforming the wavelet model from simple bivariate to multivariate time-frequency analysis. This idea can be considered a conventional way of extending simple correlation to partial correlation (Agarwal et al. 2016). Hence, the partial wavelet coherence squared of the study is computed as follows:

$$RP^2_{(y,x1,x2)} = \frac{|R(y,x1) - R(y.x2).R(y.x1|^2}{[1 - R(y,x2]^2\,[1 - R(x1,x2]^2} \quad \text{[Eqn 28]}$$

The magnitude square value $RP^2_{(y,x1,x2)}$ represents the partial correlation in the time-frequency space between y and $x1$ after any linear relationship with $x2$ has been eliminated from y and $x1$.

Limitations of the methodology

While wavelet coherence analysis provides a deeper insight into the dynamics of variable co-movement by estimating the spectral characteristics of a time series over time, revealing the evolution of its periodic components, extending this analysis to multiple variables presents significant challenges (Sun & Xu 2018). Consequently, our study is limited to examining three variables by adopting a partial wavelet technique.

Data and results

Data description and summary statistics

The data used in our study span from 2000 to 2022 and are sourced from two databases for 26 African countries. Firstly, income inequality was sourced from the Standardised World Income Inequality Database (SWIID).[3] Secondly, the GDP growth variable was sourced from the WBDI.[4] Thirdly,

3.https://fsolt.org/swiid/.

4.https://databank.worldbank.org/source/world-development-indicators.

the land ownership measure is the authors' own computations. Note that the data length and choice of African countries are solely based on data availability.

Table 1 presents the descriptive statistics of the time series for the 26 African countries, revealing interesting stylised facts. For instance, Southern African countries such as Namibia, Zambia, Lesotho, Mozambique and Zimbabwe have the lowest average land ownership compared to other African countries (Bernstein 2003). Conversely, West and East African countries, such as Burundi, Rwanda, Uganda, Benin, Nigeria and Burkina Faso, record higher averages of land ownership, confirming the notion that these countries are the most egalitarian in the continent (Frankema 2005). Further, considering that Southern and Central African (West and East African) countries have marginally higher (lower) income Gini averages, we speculate a possible negative relationship between land ownership and income inequality in our sample. These methods are discussed below and we present a formal analysis to test this proposition in the regression and wavelet sections.

Cross dependency and stationarity test

We commence our analysis by examining cross-sectional dependence among the nations to explore the causal link between land ownership and income inequality. To accomplish this, we utilise three distinct cross-sectional dependence tests: the Lagrange Multiplier (LM) test by Breusch and Pagan (1980), the Cross-Section Dependence (CD) test by Pesaran (2004) and the Bias-Adjusted Cross-Sectionally Dependent Lagrange Multiplier (CDLM) test by Pesaran, Shin and Smith (1999). The findings, illustrated in Table 2, reveal that all cross-sectional dependence tests indicate a significant cross-sectional dependence among the nations concerning the three variables. This observation implies that the effect of land inequality in one country can spread beyond borders. Based on the evidence of cross-sectional dependence, we proceeded with second-generation unit root tests, specifically the Im, Pesaran and Shin (CIPS) test developed by Pesaran (2007) and the Maddala and Wu (1999) (CADF) test, to evaluate the stationarity of the variables. The unit root test results indicate that while some variables were non-stationary at level, they all attained stationarity after taking the first difference.

Cointegration analysis and causality tests

Table 3 presents the results of the Pooled mean group cointegration estimation analysis, while Table 4 displays the outcomes of the causality test. The PMG estimators show a positive and statistically significant long-run relationship between land ownership and income inequality regardless of

TABLE 1: Descriptive statistics.

Country	Land ownership per sq.km		Income Gini		GDP growth	
	Mean	SD	Mean	SD	Mean	SD
West African countries						
Burkina Faso	35.21	4.410000	0.437304	0.021370	5.360000	2.00
Benin	53.63	4.560000	0.443391	0.026856	4.680000	1.76
Cameroon	30.71	5.200000	0.442130	0.014053	3.970000	1.39
Ivory Coast	19.38	1.850000	0.457565	0.003217	3.680000	4.47
Gambia	32.40	2.590000	0.442043	0.018195	3.200000	4.00
Guinea	13.35	2.230000	0.396870	0.020406	4.500000	2.65
Liberia	21.68	1.910000	0.361522	0.005767	2.400000	7.96
Mali	7.58	1.370000	0.397130	0.007479	4.470000	3.44
Nigeria	39.08	6.500000	0.442783	0.004188	5.150000	3.69
Senegal	15.40	1.950000	0.411043	0.010151	4.130000	1.92
Sierra Leone	21.16	2.090000	0.412087	0.009525	5.460000	8.79
Togo	30.53	4.280000	0.435826	0.007941	3.770000	3.12
East African countries						
Burundi	88.75	18.320000	0.387652	0.004292	2.400000	2.50
Ethiopia	54.53	14.570000	0.333435	0.005798	8.520000	3.63
Kenya	28.77	4.570000	0.463565	0.004860	4.280000	2.27
Rwanda	83.12	8.630000	0.507304	0.004577	7.420000	3.35
Tanzania	21.04	3.200000	0.440087	0.006646	5.990000	1.33
Uganda	58.23	6.530000	0.437087	0.013270	5.910000	2.19
South and Central African countries						
Chad	8.25	1.830000	0.419217	0.016933	5.650000	8.49
DRC	34.75	3.860000	0.432652	0.011400	4.880000	3.66
Lesotho	7.70	0.306554	0.498957	0.008293	2.100000	2.99
Malawi	110.59	12.820000	0.462348	0.007371	3.980000	3.07
Mozambique	7.73	2.050000	0.464130	0.007002	5.910000	3.02
Namibia	0.62	0.064873	0.654174	0.005441	3.280000	3.86
Zimbabwe	8.90	2.030000	0.476826	0.012865	0.627838	9.74
Zambia	7.45	1.040000	0.565522	0.025023	5.380000	2.82

SD, standard deviation; GDP, gross domestic product; DRC, Democratic Republic of Congo.

which series is the dependent variable in the regression. These results contradict the conventional literature, which suggests that an increase in land ownership reduces income inequality (Carter 2000; Cipollina et al. 2018; Qasim et al. 2020). Moreover, we observe that GDP exerts a significant and positive (insignificant) long-run relationship with income inequality (land inequality), which is consistent with the Kuznets curve, which hypothesises that countries with low-income levels (such as African countries) have a positive inequality-growth relationship (Amponsah, Agbola & Mahmood 2023; Fosu 2010; Mdingi & Ho 2021). Further, note that short-run dynamics are insignificant; the error correction term produces the expected negative and significant estimate when land inequality is the dependent variable, whereas cointegration effects are verified when Pedroni's (1999) panel v-test statistic is used. Lastly, the causality tests (Table 4) confirm bidirectional causality between income and land inequality as well as between land inequality and GDP, whereas unidirectional causality runs from income inequality to GDP.

TABLE 2a: Cross dependency and stationarity test.

Test	Statistic	*df*	Prob.
Breusch-Pagan LM	2264.88	351	0.0000
Pesaran scaled LM	72.24	-	0.0000
Pesaran CD	27.64	-	0.0000

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

LM, Lagrange multiplier; CD, cross-section dependence; GDPG, Gross Domestic Product Growth Rate; CADF, Cross-sectionally Augmented Dickey-Fuller; CIPS, Cross-sectionally Im-Pesaran-Shin.

TABLE 2b: Cross dependency and stationarity test.

Variable	Maddala and Wu (1999) (CADF)		Pesaran (2007) (CIPS)	
	Level	1st Difference	Level	1st Difference
Stationarity test				
L/O	-0.538	-2.56***	-0.493	3.89***
I/I	1.12	-1.54	-1.26	-4.22***
GDPG	-2.23***	-3.32***	-3.55***	-5.63***

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

LM, Lagrange multiplier; CD, cross-section dependence; GDPG, Gross Domestic Product Growth Rate; CADF, Cross-sectionally Augmented Dickey-Fuller; CIPS, Cross-sectionally Im-Pesaran-Shin.

TABLE 3: Pooled mean group cointegration estimation.

Dependent variable	Dependent variable	
	Land ownership	Income inequality
Panel A: Long-run		
II	27.07 (0.0181)**	N/A
LO	N/A	0.000565 (0.0048)***
GDP	0.009838 (0.4670)	0.002799 (0.0000)***
Panel B: Short-run		
ΔII	-12.39 (0.5660)	-
ΔLO	-	-0.048383 (0.3495)
ΔGDP	0.019392 (0.3213)	5.41E-05 (0.6583)
ECT(−1)	-0.050676 (0.0116)**	-0.000964 (0.9832)
Panel C: Cointegration tests		
Panel v-statistic	4.28 (0.0000)***	2.33 (0.0101)**
Panel rho-statistic	2.19 (0.9855)	0.771325 (0.7797)
Panel PP-statistic	0.685742 (0.7536)	1.422888 (0.9226)
Panel ADF-statistic	1.20 (0.8851)	-2.11 (0.0174)**
Group rho-statistic	3.76 (0.9999)	1.61 (0.9458)
Group PP-statistic	1.67 (0.9517)	0.080265 (0.5320)
Group ADF-statistic	1.16 (0.8758)	-1.67 (0.0476)*

Note: Probability values reported in parentheses.

***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

GDP, gross domestic product; ADF, Augmented Dickey-Fuller; PP, Phillips Perron.

Altogether, our results indicate a positive relationship between land ownership and income inequality with bidirectional causality between the two variables. These findings can be explained as follows. Firstly, countries with high levels of land ownership can lead to high levels of income inequality when societies have highly skewed land distributions, predatory land practices and high levels of urbanisation (Faguet, Sánchez & Villaveces 2020). Secondly, countries with low levels of ownership can also have low levels of income inequality when the concentration of land in large farm holdings is coupled with efficient land use and investment, which generate widespread economic benefits (Lipton & Saghai 2017; Wegerif & Guerena 2020). Nonetheless, we consider our panel estimates presented thus far to be at odds with theoretical expectations. This could be because of the importance of cross-sectional differences among the countries, as revealed in the cross-sectional dependency results. Therefore, we present country-specific evidence using a time-frequency analysis in the following subsection.

Wavelet coherence analysis

Next, we examine the results obtained from the wavelet coherence analysis, which evaluates the frequency of co-movement between land ownership and income inequality across a sliding time window. This approach serves as an analogy to the correlation coefficient in the time-frequency domain. Wavelet coherency outcomes were captured within a two-dimensional matrix consisting of complex numbers. These results can be visually represented through a wavelet coherence spectrum plot that assesses the strength (coherency) and patterns (phase dynamics) of the synchronisation of the time series across various time scales.

Wavelet coherency plots measure the strength of coherency using colour contours, where cooler colours indicate weak coherence and warmer colours indicate strong coherence. Furthermore, the dynamics of relative phase differences provide insights into lead-lag dynamics, that is, whether 'land inequality' precedes 'income inequality' or vice versa. The orientation of the arrows represents the 'sign of the relationship', indicating whether it is positive or negative. Within the time-frequency space, four possible outcomes can be observed based on the phase difference dynamics:

- Firstly, land inequality and income inequality are in-phase or positively correlated with land inequality leading to income inequality if the arrow orientation is ↑, ↗ and →.

TABLE 4: Pairwise Dumitrescu-Hurlin causality tests.

Null hypothesis	W-stat	Zbar statistic	*P*
Land ownership does not cause income inequality	6.84	8.79	0.0000***
Income inequality does not cause land ownership	11.72	18.22	0.0000***
Land ownership does not cause GDP	3.84	2.99	0.0028***
GDP does not cause land ownership	3.66	2.64	0.0084***
Income inequality does not cause GDP growth	3.69	2.71	0.0069***
GDP growth does not cause income inequality	2.81	0.99940	0.3176

***, denote significance at the 1%.

GDP, gross domestic product.

- Secondly, land inequality and income inequality are in-phase or positively correlated with income inequality leading to land inequality if the arrow orientation is ↘.
- Thirdly, land inequality leading to income inequality is anti-phase or negatively correlated with land inequality, leading to income inequality if the arrow orientation is ↓, ↙ and ←.
- Fourthly, land inequality and income inequality are in-phase or positively correlated with income inequality leading to land inequality if the arrow orientation is ↖.

From the wavelet coherence plots for the 26 African countries reported in Online Appendix 1, we observe two frequency bands for most countries. We summarise the phase dynamics within the frequency bands for each country in Table 5 and further group these countries into three categories:

- The first group consists of eight countries that find in-phase or positive co-movement between land ownership and income inequality. In six of these countries (Benin, Nigeria, Togo, Sierra Leone, Ethiopia, Tanzania, Zambia and Zimbabwe), we observe that land ownership causes income inequality, whereas for the remaining country (Rwanda), reverse causality is found.
- The second group consists of 16 countries that find anti-phase or negative co-movement between land ownership and income inequality. In three countries (Malawi, Mozambique and Senegal), land inequality causes income inequality, in eight countries (Burundi, Cameroon, Chad, Democratic Republic of Congo, Kenya, Lesotho, Mali and Uganda), reverse causality is observed, while in the remaining five countries (Gambia, Guinea, Ivory Coast, Liberia and Namibia), there are causality switching dynamics between the frequency bands.
- The third group of countries does not find any significant phase dynamics or co-movements between the series, that is, Burundi and Zimbabwe.

In further disseminating our findings, we note that most countries that found in-phase or positive land ownership-income inequality co-movements did not implement formal land reforms in the post-2000 period: Ethiopia, Nigeria, Sierra Leone, Togo and Zambia. Conversely, most countries that find a negative relationship between land ownership and income inequality have implemented new reforms in the post-2000 period: Malawi, Mali, Namibia, Burkina Faso, Lesotho, Kenya and Liberia. An exceptional case exists for Burundi and Zimbabwe (Benin, Rwanda and Tanzania), which implemented reforms in the post-2000 period but produced unexpectedly insignificant (positive and significant)

TABLE 5: Summary of wavelet coherence results.

Countries	First frequency band				Second frequency band			
	Period	Cycle	±	Lead/Lag	Period	Cycle	±	Lead/Lag
Panel A: Countries with in-phase dynamics								
Benin	2000–2007	0–2 years	+	LO→II	N/A	N/A	N/A	N/A
Ethiopia	N/A	N/A	N/A	N/A	2015–2022	0–6 years	+	LO→II
Nigeria	2000–2010	0–8 years	+	LO→II	2010–2022	0–8 years	+	LO→II
Sierra Leone	N/A	N/A	N/A	N/A	2015–2022	0–8 years	+	LO→II
Rwanda	2000–2002	0–3 years	+	II→LO	N/A	N/A	N/A	N/A
Tanzania	2010–2022	0–8 years	+	LO→II	2010–2022	0–8 years	+	LO→II
Togo	2000–2010	0–8 years	+	LO→II	2010–2022	0–8 years	+	LO→II
Zambia	2000–2014	0–5 years	+	LO→II	2015–2022	3–5 years	+	LO→II
Panel B: Countries with anti-phase dynamics								
Burkina Faso	2000–2010	0–4 years	−	LO→II	2013–2020	3–7 years	−	LO→II
Cameroon	N/A	N/A	N/A	N/A	2015–2022	6–8 years	−	II→LO
Chad	N/A	N/A	N/A	N/A	2015–2022	0–8 years	−	II→LO
DRC	2000–2005	0–3 years	−	II→LO	2014–2022	5–8 years	−	II→LO
Ivory Coast	2000–2005	0–3 years	−	LO→II	2016–2020	0–2 years	−	II→LO
Gambia	2000–2005	0–3 years	−	LO→II	2014–2020	0–4 years	−	II→LO
Guinea	2000–2010	0–8 years	−	LO→II	2010–2020	0–8 years	−	II→LO
Kenya	2000–2010	0–8 years	−	II→LO	2010–2022	0–8 years	−	II→LO
Lesotho	2000–2002	0–5 years	−	II→LO	2020–2022	0–2 years	−	II→LO
Liberia	2000–2005	0–4 years	−	LO→II	2011–2020	0–8 years	−	II→LO
Mali	2000–2007	0–6 years	−	II→LO	2015–2020	0–6 years	−	II→LO
Malawi	2000–2007	0–8 years	−	LO→II	2018–2022	0–3 years	−	LO→II
Mozambique	2000–2002	0–2 years	−	LO→II	2018–2022	0–2 years	−	LO→II
Namibia	2000–2010	0–8 years	−	LO→II	2011–2022	0–8 years	−	II→LO
Senegal	2000–2005	0–2 years	−	LO→II	2010–2015	0–2 years	−	LO→II
Uganda	N/A	N/A	N/A	N/A	2011–2020	2–6 years	−	II→LO
Panel C: Countries with no co-movements								
Burundi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zimbabwe	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

DRC, Democratic Republic of Congo.

relationships between the variables. For these latter countries, we conclude that perverse relationships occur because of the failure of newer reforms to address land ownership in a manner that is beneficial to society.

Partial wavelet coherence results

Lastly, we present the partial wavelet coherence analysis after controlling for the influence of the GDP growth rate on the land-inequality relationship. As reported in Online Appendix 2, the partial wavelet coherence plots do not show any significant differences when compared with the wavelet coherence results for Burundi, Burkina Faso, Cameroon, Chad, Democratic Republic of Congo, Ethiopia, Gambia, Guinea, Kenya, Liberia, Namibia, Rwanda, Tanzania, Togo, Sierra Leone and Zimbabwe. However, slight changes are observed in countries such as Benin, Ivory Coast, Lesotho, Malawi, Mali, Mozambique, Nigeria, Senegal, Uganda and Zambia, but they are not substantial enough to change the phase dynamics. Altogether, we treat our findings from the wavelet coherence analysis with a fair amount of confidence because the results generally remain the same after controlling for economic growth in the partial correlations.

Conclusion

We examined the extent to which land ownership affects income inequality in Africa. We create a unique time series that measures the number of landowners per square kilometre of agricultural land and examine its relationship with income inequality for 26 African countries between 2000 and 2022 using conventional cointegration and causality analysis, as well as more advanced wavelet coherence techniques. Conventional cointegration and causality analyses indicate a positive long-run relationship between land ownership and income inequality, with bidirectional causality between the variables. The complex wavelet analysis further picks up discrepancies in the results for individual countries, with eight countries finding a positive relationship, 16 countries finding a negative relationship and two countries finding an insignificant relationship. In further discerning our empirical results, we note that countries with the theoretically expected negative relationship between land inequality relationships are observed for countries that implemented land reforms in the post-2000 period, whereas countries with a positive land inequality relationship had reforms in the pre-2000 period. These results remain robust, even when controlling for economic growth in a partial wavelet coherence framework.

Therefore, what can policymakers learn from this study? Firstly, it highlights the importance of continuously upgrading land policy reforms to ensure a more equitable distribution of land that promotes a more egalitarian society in Africa. Our findings indicate that countries that do not undergo continuous adjustments in land reforms are at risk of experiencing higher levels of land ownership without improving their income inequality. In particular, countries with more 'insecure' customary and private land tenures make it easier for 'locals' and 'outsiders' to exploit indigenous land and thereby exacerbate income and wealth inequality. Secondly, even for countries that have previously undergone land policy reforms, these governments should be careful as evidence of the reverse causality experienced in the post-reform period, indicating that other factors causing income inequality can lead to changes in land ownership. At the forefront of these factors is gender inequality in farmland holdings, which has been documented to be significantly larger in African countries than in other regions. Policymakers need to devise policies and laws geared towards improving the property ownership rights of women, especially under customary law.

Moving forward, we propose that both academics and policymakers alike consider the impact that educational inequality, as an important dimension of societal inequality, can have on land inequality. In theory, higher land acquisition can affect human capital development if the proceeds from land use are used for education and skill development purposes. However, to the best of our knowledge, the proposition that educational inequality can affect land acquisition has not been addressed theoretically or empirically. Future studies could consider endogenous channels such as improved technical knowledge and entrepreneurial innovation as transmission mechanisms through which improved educational equality can simultaneously improve land and income inequality.

Expanded policy implications

The findings from our wavelet coherence analysis have significant implications for policymakers, particularly regarding land reform policies in African countries. The observed phase dynamics between land ownership and income inequality highlight the nuanced and complex relationships that can inform targeted and effective policy interventions:

- **Positive co-movement and lack of reforms:** In countries such as Ethiopia, Nigeria, Sierra Leone, Togo and Zambia, where a positive co-movement between land ownership and income inequality was observed, our findings suggest that the absence of formal land reforms since the 2000s may have exacerbated income inequality. Policymakers in these nations should consider implementing comprehensive land reforms to address the concentration of land ownership, as this could be a critical lever in reducing income inequality. Ensuring inclusive and equitable land policies could prevent further entrenchment of income disparities.
- **Negative co-movement and implementation of reforms:** Conversely, countries such as Malawi, Mali, Namibia and Kenya, which have implemented land reforms and exhibit negative co-movements, demonstrate the potential effectiveness of such reforms in mitigating income inequality. These cases underscore the importance of continuing and possibly expanding land reform initiatives, ensuring that legal frameworks and enforcement mechanisms adequately support them. Policymakers should also focus on maintaining

transparency and accountability in the implementation process to maximise the benefits of these reforms for broader segments of the population.

- **Challenges in reform implementation:** The exceptional cases of Burundi, Zimbabwe and Benin, where land reforms did not yield the expected outcomes, highlight the challenges in reform implementation. For these countries, it is crucial to reassess the design and execution of land reforms. Policymakers should investigate the barriers to successful reform outcomes, such as issues related to governance, land tenure security or the socio-political context. Tailored interventions that address these specific challenges may be necessary to ensure that land reforms contribute to reducing income inequality.
- **Causality and policy timing:** The presence of causality-switching dynamics in countries such as Gambia, Guinea and Ivory Coast suggests that the relationship between land ownership and income inequality is not static. This finding emphasises the need for dynamic and adaptable policy approaches that can respond to changing conditions over time. Policymakers should consider the timing of interventions and the potential for reforms to have different effects at various stages of implementation.

By incorporating these policy implications into our analysis, we aim to provide actionable insights that can guide future land reform initiatives and contribute to reducing income inequality in African countries.

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Authors' contributions

R.R. was responsible for the conceptualisation, methodology, software, formal analysis, investigation, resources, data curation, writing of the original draft and visualisation. A.P. was responsible for conceptualisation, validation, investigation, resources, data curation, writing, reviewing and editing, visualisation, supervision and project administration.

Ethical considerations

This article followed all ethical standards for research.

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Data availability

The data that support the findings of this study are available on request from the corresponding author, R.R.

Disclaimer

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References

Acemoglu, D., Chaves, I.N., Osafo-Kwaako, P. & Robinson, J. A., 2014, 'Indirect rule and state weakness in Africa: Sierra Leone in comparative perspective', in *African successes, volume IV: Sustainable growth*, pp. 343–370, National Bureau of Economic Research, Inc., Cambridge, MA.

Acemoglu, D., Johnson, S. & Robinson, J.A., 2002, 'Reversal of fortune: Geography and institutions in the making of the modern world income distribution', *The Quarterly Journal of Economics* 117(4), 1231–1294. https://doi.org/10.1162/003355302320935025

Acemoglu, D. & Robinson, J.A., 2010, 'Why is Africa poor?', *Economic History of Developing Regions* 25(1), 21–50. https://doi.org/10.1080/20780389.2010.505010

Acemoglu, D. & Robinson, J.A., 2012, 'Why nations fail: The origins of power, prosperity, and poverty', *Finance and Development-English Edition* 49(1), 53. https://doi.org/10.1355/ae29-2j

Africa Development Report, 2012, Towards green growth in Africa, African Development Bank (AfDB) Group, viewed 22 November 2023, from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African_Development_Report_2012.pdf.

Agarwal, A., Maheswaran, R., Sehgal, V., Khosa, R., Sivakumar, B. & Bernhofer, C., 2016, 'Hydrologic regionalization using wavelet-based multiscale entropy method', *Journal of Hydrology* 538, 22–32. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African_Development_Report_2012.pdf

Aguiar-Conraria, L. & Soares, M.J., 2014, 'The continuous wavelet transform: Moving beyond uni-and bivariate analysis', *Journal of Economic Surveys* 28(2), 344–375. https://doi.org/10.1111/joes.12012

Amponsah, M., Agbola, F.W. & Mahmood, A., 2023, 'The relationship between poverty, income inequality and inclusive growth in sub-Saharan Africa', *Economic Modelling* 126, 106415. https://doi.org/10.1016/j.econmod.2023.106415

Anseeuw, W. & Baldinelli, G.M., 2020, *Land inequality at the heart of unequal societies.* Research findings from the land inequality initiative, p. 76, Synthesis Report, International Fund for Agricultural Development (IFAD), Rome.

Aspromourgos, T., 1998, 'On the origins of classical economics: Distribution and value from William Petty to Adam Smith', *Capital & Class* 22(1), 142–143. https://doi.org/10.4324/9780203434222

Ayaz, M. & Mughal, M., 2023, 'Land inequality and landlessness in Pakistan: Measuring the diverse nature of land disparities', *Land Use Policy* 131, 106720. https://doi.org/10.1016/j.landusepol.2023.106720

Azadi, H. & Vanhaute, E., 2019, 'Mutual effects of land distribution and economic development: Evidence from Asia, Africa, and Latin America', *Land* 8(6), 96. https://doi.org/10.3390/land8060096

Bambio, Y. & Agha, S.B., 2018, 'Land tenure security and investment: Does strength of land right really matter in rural Burkina Faso?', *World Development* 111, 130–147. https://doi.org/10.1016/j.worlddev.2018.06.026

Barro, R.J. & Lee, J.W., 2001, 'International data on educational attainment: updates and implications', *Oxford Economic Papers* 53(3), 541–563. https://doi.org/10.1093/oep/53.3.541

Bauluz, L., Govind, Y. & Novokmet, F., 2020, 'Global land inequality', PSE Working Papers halshs-03022360, HAL.

Bernstein, H., 2003, 'Land reform in Southern Africa in world-historical perspective', *Review of African Political Economy* 30(96), 203–226. https://doi.org/10.1080/03056244.2003.9693495

Berry, S., 2002, 'Debating the land question in Africa', *Comparative Studies in Society and History* 44(4), 638–668. https://doi.org/10.1017/S0010417502000312

Birdsall, N. & Londoño, J.L., 1997, 'Asset inequality matters: An assessment of the World Bank's approach to poverty reduction', *The American Economic Review* 87(2), 32–37, viewed 28 November 2023, from https://EconPapers.repec.org/RePEc:aea:aecrev:v:87:y:1997:i:2:p:32-37.

Bjornlund, V., Bjornlund, H. & Van Rooyen, A.F., 2020, 'Why agricultural production in sub-Saharan Africa remains low compared to the rest of the world – A historical perspective', *International Journal of Water Resources Development* 36(Suppl. 1), S20–S53. https://doi.org/10.1080/07900627.2020.1739512

Blaug, M., 1997, *Economic theory in retrospect*, Cambridge University Press, Cambridge.

Boone, C., Dyzenhaus, A., Manji, A., Gateri, C.W., Ouma, S., Owino, J.K. et al., 2019, 'Land law reform in Kenya: Devolution, veto players, and the limits of an institutional fix', *African Affairs* 118(471), 215–237. https://doi.org/10.1093/afraf/ady053

Breusch, T.S. & Pagan, A.R., 1980, 'The Lagrange multiplier test and its applications to model specification in econometrics', *The Review of Economic Studies* 47(1), 239–253.

Brown, D., 2017, 'Social dimensions of land rights reform in Liberia: Some unresolved issues and policy dilemmas', *Development Policy Review* 35, O270–O286. https://doi.org/10.1111/dpr.12322

Byamugisha, F.F., 2013, *Securing Africa's land for shared prosperity: A program to scale up reforms and investments*, World Bank Publications, Washington, DC.

Carter, M.R., 2000, *Land ownership inequality and the income distribution consequences of economic growth*, viewed n.d., from https://ideas.repec.org/s/ags/widerw.html.

Chancel, L., Cogneau, D., Gethin, A., Myczkowski, A. & Robilliard, A.S., 2023, 'Income inequality in Africa, 1990–2019: Measurement, patterns, determinants', *World Development* 163, 106162. https://doi.org/10.1016/j.worlddev.2022.106162.

Chikaya-Banda, J. & Chilonga, D., 2021, 'Key challenges to advancing land tenure security through land governance in Malawi: Impact of land reform processes on implementation efforts', *Land Use Policy* 110, 104994. https://doi.org/10.1016/j.landusepol.2020.104994

Chinsinga, B., 2011, 'The politics of land reforms in Malawi: The case of the Community Based Rural Land Development Programme (CBRLDP)', *Journal of International Development* 23(3), 380–393. https://doi.org/10.1002/jid.1776

Cipollina, M., Cuffaro, N. & D'Agostino, G., 2018, 'Land inequality and economic growth: A meta-analysis', *Sustainability* 10(12), 1–20. https://doi.org/10.3390/su10124655

Colson, E., 1971, 'The impact of the colonial period on the definition of land rights', *Colonialism in Africa* 1960(3), 193–215.

Cornia, G.A., 2019, 'Sub-Saharan Africa's diverging inequality trends, 1991–2011: A structuralist interpretation 1', *Revue d'économie du développement* 27(2), 9–43. https://doi.org/10.3917/edd.332.0009

Cornia, G.A., Odusola, A., Bhorat, H. & Conceição, P., 2017, *Income inequality trends in sub-Saharan Africa divergence, determinants and consequences: Introduction, motivation and overview (No. 2063-2018-609)*, viewed n.d., from https://ideas.repec.org/s/ags/undpar.html.

Deininger, K. & Olinto, P., 1999, 'Asset distribution, inequality, and growth', Policy Research Working Paper Series 2375, The World Bank.

Deininger, K. & Squire, L., 1998, 'New ways of looking at old issues: Inequality and growth', *Journal of Development Economics* 57(2), 259–287. https://doi.org/10.1016/S0304-3878(98)00099-6

Delville, P.L., 2020, 'Analyzing the Benin Land Law: An alternative viewpoint of progress', *Land Use Policy* 94, 104521. https://doi.org/10.1016/j.landusepol.2020.104521

Dumitrescu, E.I. & Hurlin, C., 2012, 'Testing for Granger non-causality in heterogeneous panels', *Economic Modelling* 29(4), 1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Ekpodessi, S.G.N. & Nakamura, H., 2018, 'Land use and management in Benin Republic: An evaluation of the effectiveness of Land Law 2013-01', *Land Use Policy* 78, 61–69. https://doi.org/10.1016/j.landusepol.2018.06.025

Elbow, K., 2019, 'Burkina Faso's ambitious experiment in participatory land tenure reform', *Gates Open Research* 3(856), 856. https://doi.org/10.21955/gatesopenres.1115780.1

Engelbrecht, P.J., 2014, 'Land reform in Namibia: An analysis of media coverage', Doctoral dissertation, University of Kansas.

Erickson, M.L. & Vollrath, M.D., 2004, *Dimensions of land inequality and economic development (No. 4-158)*, IMF, Washington, DC. https://doi.org/10.5089/9781451857610.001

Faguet, J.P., Sánchez, F. & Villaveces, M.J., 2020, 'The perversion of public land distribution by landed elites: Power, inequality and development in Colombia', *World Development* 136, 105036. https://doi.org/10.1016/j.worlddev.2020.105036

Fogelman, C., 2016, 'Measuring gender, development, and land: Data-driven analysis and land reform in Lesotho', *World Development Perspectives* 1, 36–42. https://doi.org/10.1016/j.wdp.2016.06.001

Fort, R., 2007, 'Land inequality and economic growth: A dynamic panel data approach', *Agricultural Economics* 37(2–3), 159–165. https://doi.org/10.1111/j.1574-0862.2007.00262.x

Fosu, A.K., 2009, 'Inequality and the impact of growth on poverty: Comparative evidence for sub-Saharan Africa', *The Journal of Development Studies* 45(5), 726–745. https://doi.org/10.1080/00220380802663633

Fosu, A.K., 2010, 'Inequality, income, and poverty: Comparative global evidence', *Social Science Quarterly* 91(5), 1432–1446. https://doi.org/10.1111/j.1540-6237.2010.00739.x

Frankema, E.H., 2005, 'The colonial origins of inequality: Exploring the causes and consequences of land distribution (No. 119)', IAI Discussion Papers, viewed from http://hdl.handle.net/10419/27410.

Galli, S. & Rönnbäck, K., 2021, 'Land distribution and inequality in a black settler colony: The case of Sierra Leone, 1792–1831', *The Economic History Review* 74(1), 115–137. https://doi.org/10.1111/ehr.13020

Gottlieb, C. & Grobovšek, J., 2019, 'Communal land and agricultural productivity', *Journal of Development Economics* 138(C), 135–152. https://doi.org/10.1016/j.jdeveco.2018.11.001

Gumede, W., 2018, *Lessons from Zimbabwe's failed land reforms*, vol. 15, University of the Witwatersrand, Johannesburg.

Hasanbasri, A., Kilic, T., Koolwal, G. & Moylan, H., 2022, *Individual wealth inequality: Measurement and evidence from low and middle income countries*, Review of Income and Wealth, World Bank, Washington, DC. https://doi.org/10.1596/1813-9450-9987

Haney, L.B., 1964, *History of economic thought*, The MacMillan Company, New York, NY.

Hubacek, K. & Van Den Bergh, J.C., 2002, *The role of land in economic theory*, International Institute for Applied Systems Analysis, Laxenburg.

Kohlhagen, D., 2011, *In quest of legitimacy: Changes in land law and legal reform in Burundi*, pp. 83–103, Palgrave Macmillan UK, London.

Kuba, R. & Lentz, C. (eds.), 2005, *Land and the politics of belonging in West Africa*, vol. 9, Brill, Leiden.

Lipton, M. & Saghai, Y., 2017, 'Food security, farmland access ethics, and land reform', *Global Food Security* 12, 59–66. https://doi.org/10.1016/j.gfs.2016.03.004

Maddala, G.S. & Wu, S., 1999, 'A comparative study of unit root tests with panel data and a new simple test', *Oxford Bulletin of Economics and statistics* 61(S1), 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Mamdani, M., 2017, *Citizen and subject: Contemporary Africa and the Legacy of Late Colonialism, with a new preface*, Wits University Press and Makerere Institute of Social Research, Johannesburg.

Manji, A., 2014, 'The politics of land reform in Kenya 2012', *African Studies Review* 57(1), 115–130. https://doi.org/10.1017/asr.2014.8

Mdingi, K. & Ho, S.Y., 2021, 'Literature review on income inequality and economic growth', *MethodsX* 8, 101402. https://doi.org/10.1016/j.mex.2021.101402

Meek, R.L., 1963, *The economics of physiocracy*, Harvard University Press, Cambridge, MA.

Mihanović, H., Orlić, M. & Pasarić, Z., 2009, 'Diurnal thermocline oscillations driven by tidal flow around an island in the Middle Adriatic', *Journal of Marine Systems* 78, S157–S168. https://doi.org/10.1016/j.jmarsys.2009.01.021

Mkodzongi, G. & Lawrence, P., 2019, 'The fast-track land reform and agrarian change in Zimbabwe', *Review of African Political Economy* 46(159), 1–13. https://doi.org/10.1080/03056244.2019.1622210

Moore, S.F., 1986, *Social facts and fabrications: 'Customary' law on Kilimanjaro, 1880–1980*, Cambridge University Press, Cambridge.

Mudau, J., Mukonza, R.M. & Ntshangase, B.A., 2018, 'A comparative overview of land reform experiences in Zimbabwe, Namibia and South Africa: A lesson that South Africa can learn from', *Journal of Public Administration* 53(2-1), 580–601, viewed 14 October 2023, from https://hdl.handle.net/10520/EJC-14867c817d.

Ochieng, C.M.O., 2020, 'Introduction', in Rethinking land reform in Africa: New ideas, opportunities and challenges, pp. 13–18, African Natural Resources Centre: Abidjan, Côte d'Ivoire.

Odusola, A., Mugisha, F., Workie, Y. & Reeves, W., 2017, 'Income inequality and population growth in Africa', in *Income inequality trends in sub-Saharan Africa:* Divergence, determinants and *consequences*, viewed n.d., from https://ideas.repec.org/p/ags/undpar/267644.html.

Pedersen, R.H., 2015, 'A less gendered access to land? The impact of Tanzania's new wave of land reform', *Development Policy Review* 33(4), 415–432. https://doi.org/10.1111/dpr.12121

Pedersen, R.H., 2016, 'Access to land reconsidered: The land grab, polycentric governance and Tanzania's new wave land reform', *Geoforum* 72, 104–113. https://doi.org/10.1016/j.geoforum.2015.12.010

Pedroni, P., 1995, *Panel cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis*, Indiana University, Bloomington.

Pedroni, P., 1999, 'Critical values for cointegration tests in heterogeneous panels with multiple regressors', *Oxford Bulletin of Economics and Statistics* 61(S1), 653–670. https://doi.org/10.1111/1468-0084.61.s1.14

Pedroni, P., 2004, 'Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis', *Econometric Theory* 20(3), 597–625. https://doi.org/10.1017/S0266466604203073

Pesaran, M.H., 2004, *General diagnostic tests for cross-section dependence in panels, Cambridge Working Papers in Economics 0435*, Faculty of Economics, University of Cambridge, Cambridge. https://doi.org/10.1007/s00181-020-01875-7

Pesaran, M.H., 2007, 'A simple panel unit root test in the presence of cross-section dependence', *Journal of Applied Econometrics* 22(2), 265–312. https://doi.org/10.1002/jae.951

Pesaran, M.H., Shin, Y. & Smith, R.P., 1999, 'Pooled mean group estimation of dynamic heterogeneous panels', *Journal of the American Statistical Association* 94(446), 621–634. https://doi.org/10.2307/2670182

Peters, P.E., 2004, 'Inequality and social conflict over land in Africa', *Journal of Agrarian Change* 4(3), 269–314. https://doi.org/10.1111/j.1471-0366.2004.00080.x

Peters, P.E., 2009, 'Challenges in land tenure and land reform in Africa: Anthropological contributions', *World Development* 37(8), 1317–1325. https://doi.org/10.1016/j.worlddev.2008.08.021

Phiri, A. & Ngeendepi, E., 2021, 'Do FDI and public investment crowd in/out domestic private investment in the SADC region?', *Managing Global Transitions* 19(1), 3–25. https://doi.org/10.26493/1854-6935.19.3-25

Pottier, J., 2006, 'Land reform for peace? Rwanda's 2005 land law in context', *Journal of Agrarian Change* 6(4), 509–537. https://doi.org/10.1111/j.1471-0366.2006.00133.x

Pritchard, M.F., 2013, 'Land, power and peace: Tenure formalization, agricultural reform, and livelihood insecurity in rural Rwanda', *Land use Policy* 30(1), 186–196. https://doi.org/10.1016/j.landusepol.2012.03.012

Qasim, M., Pervaiz, Z. & Chaudhary, A.R., 2020, 'Do poverty and income inequality mediate the association between agricultural land inequality and human development?', *Social Indicators Research* 151, 115–134. https://doi.org/10.1007/s11205-020-02375-y

Raimi, R. & Phiri, A., 2024, 'Examining the income gap-gender inequality nexus in Africa using bi-wavelet and partial wavelet coherence analysis', *African Journal of Science, Technology, Innovation and Development* 16(3), 410–424. https://doi.org/10.1080/20421338.2024.2328999

Spear, T., 2003, 'Neo-traditionalism and the limits of invention in British Colonial Africa', *The Journal of African History* 44(1), 3–27. https://doi.org/10.1017/S0021853702008320

Sun, Q. & Xu, W., 2018, 'Wavelet analysis of the co-movement and lead–lag effect among multi-markets', *Physica A: Statistical Mechanics and its Applications* 512, 489–499. https://doi.org/10.1016/j.physa.2018.08.102

Taylor, C.L. & Hudson, M.C., 1972, *World handbook of political and social indicators*, 2nd edn., Yale University Press, New Haven, CT.

Tchatchoua-Djomo, R., 2018, 'Improving local land governance? Exploring the linkages between land governance reforms, institutional pluralism and tenure security in Burundi', *The Journal of Legal Pluralism and Unofficial Law* 50(1), 31–55. https://doi.org/10.1080/07329113.2017.1419403

Torrence, C. & Compo, G.P., 1998, 'A practical guide to wavelet analysis', *Bulletin of the American Meteorological Society* 79(1), 61–78. https://doi.org/10.1175/1520-0477(1998)079%3C0061:APGTWA%3E2.0.CO;2

Totin, E., Segnon, A., Roncoli, C., Thompson-Hall, M., Sidibé, A. & Carr, E.R., 2021, 'Property rights and wrongs: Land reforms for sustainable food production in rural Mali', *Land Use Policy* 109, 105610. https://doi.org/10.1016/j.landusepol.2021.105610

Wegerif, M.C. & Guereña, A., 2020, 'Land inequality trends and drivers', *Land* 9(4), 101. https://doi.org/10.3390/land9040101

Zeevi, Y. & Coifman, R., 1998, *Signal and image representation in combined spaces*, Academic Press, San Diego.